

# Laser Peening for U.S. Army Helicopters

Contract No. W911NF-06-2-0034

Technology Overview  
Army Research Laboratory  
Aberdeen Proving Ground, MD



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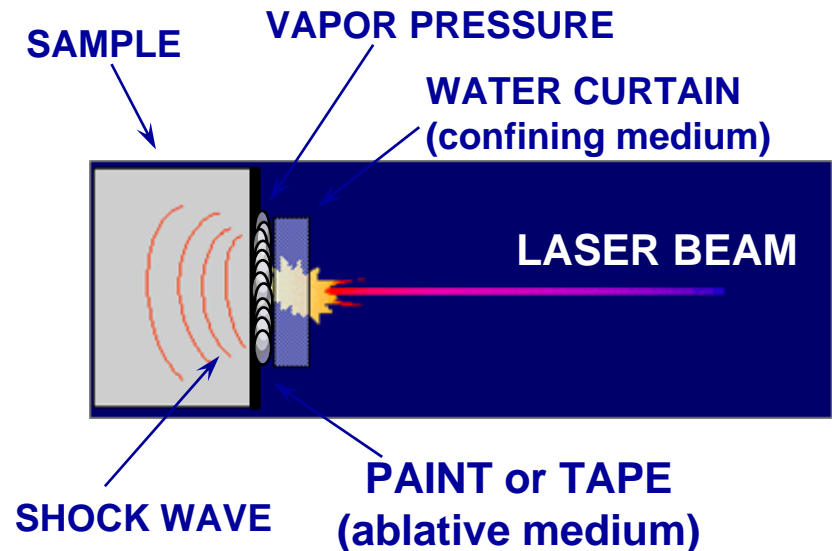
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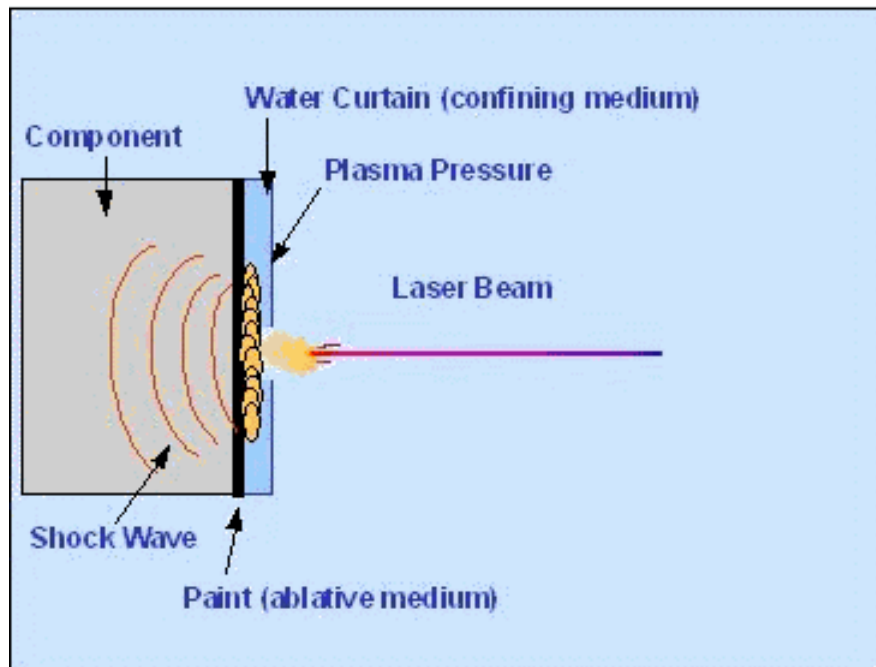
**Laser Shock Peening** is an innovative process for introducing deep compressive residual stresses into the surface of metallic parts

## Material Property Improvements Include Increased:

- Fatigue strength and fatigue life
- Resistance to crack initiation and propagation
- Resistance to fretting fatigue and wear
- Resistance to stress corrosion cracking



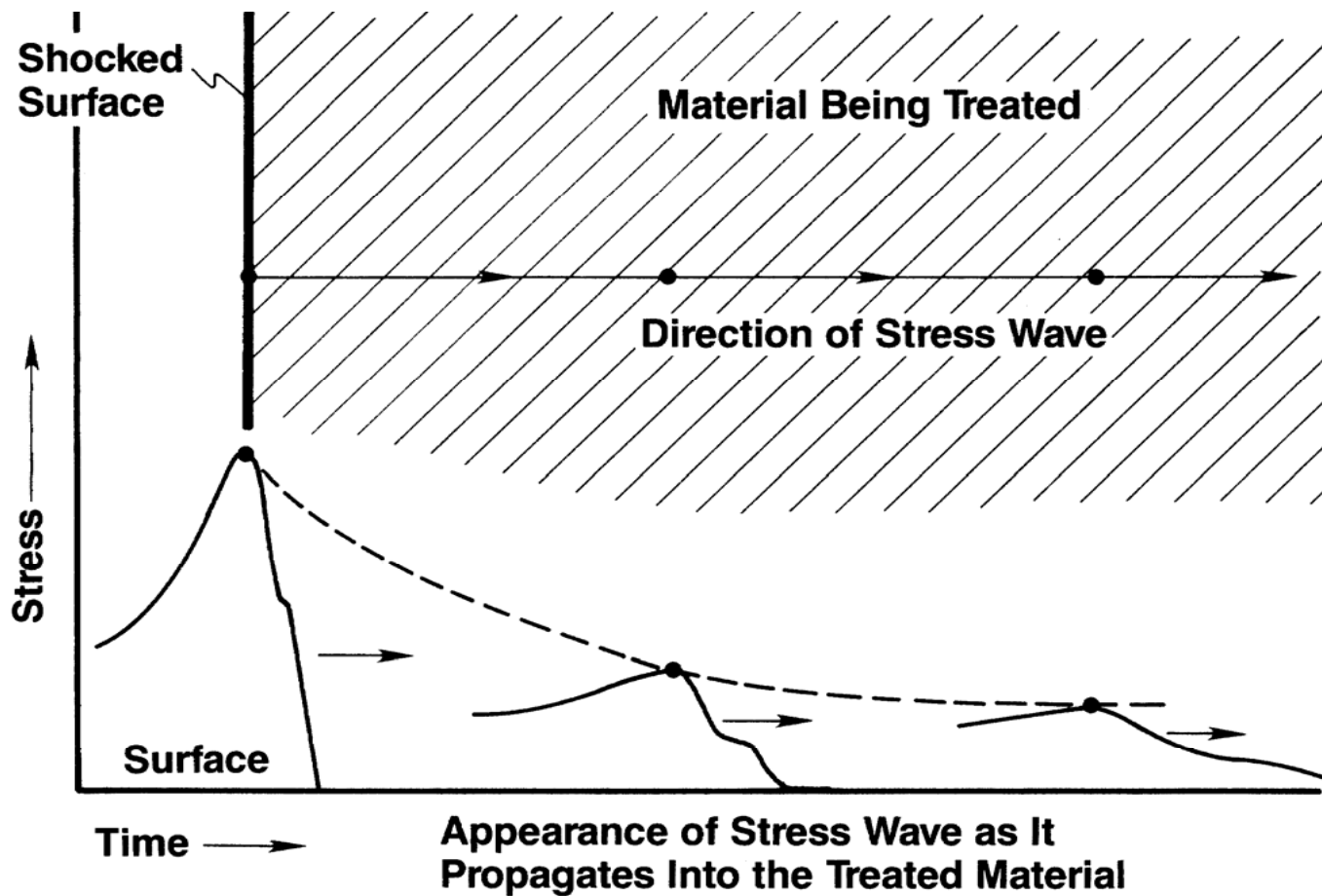
Laser peening is not a thermal treatment; it creates deep compressive residual stresses in the surface of a part with a shock wave created by high intensity laser pulses that mechanically cold-work the surface.



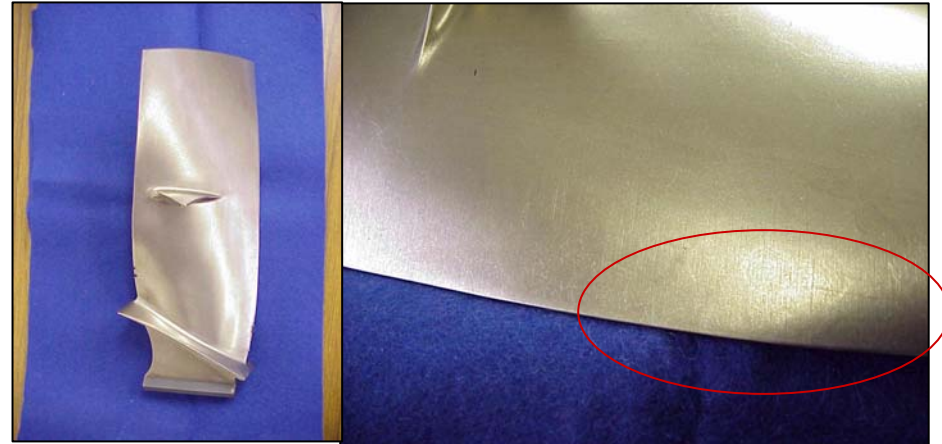
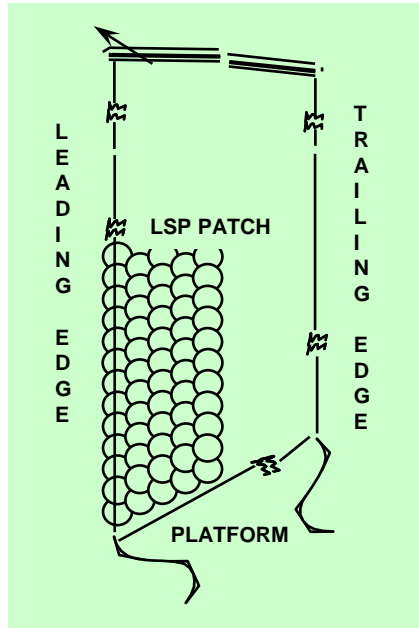
Before processing, an opaque overlay (typically black paint or tape) and a transparent overlay (typically flowing water) are applied to the surface to be laser peened.

The laser pulse passes through the transparent overlay and strikes the opaque overlay causing it to begin to vaporize. The vapor absorbs the remaining laser light and produces a rapidly expanding plasma plume.

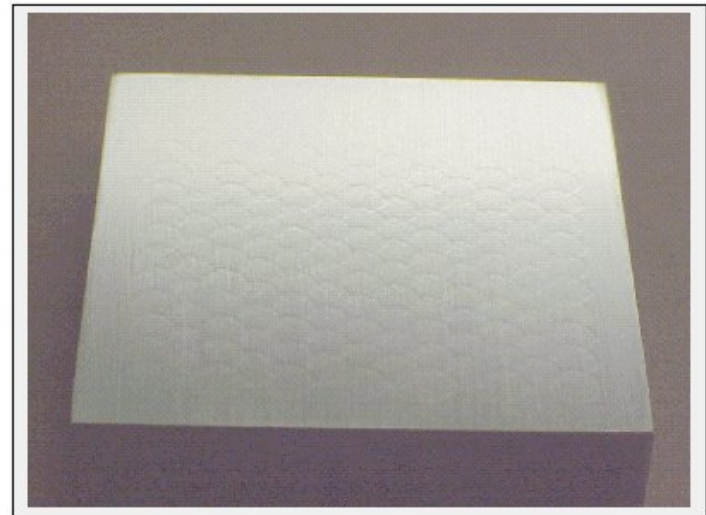
# Stress Wave Propagation



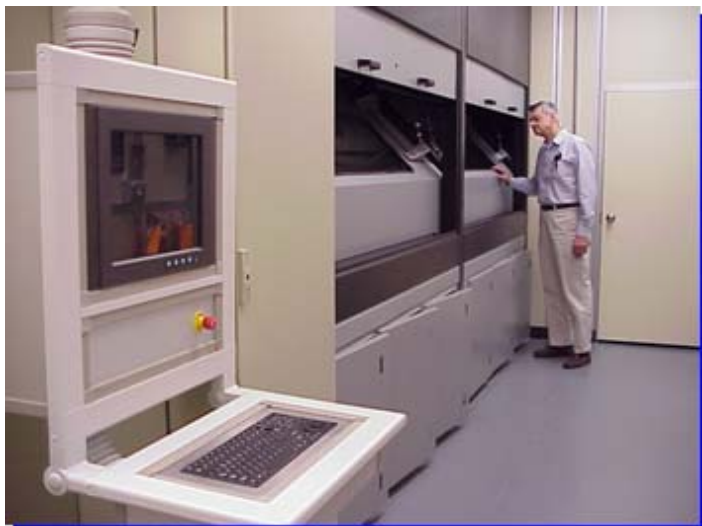
# Laser Shock Peening



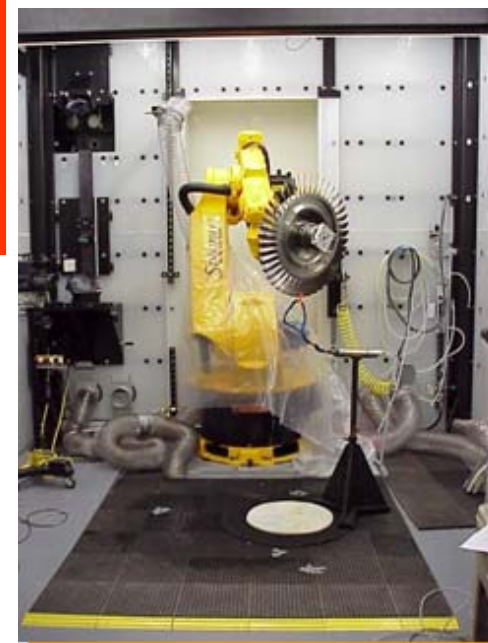
- A pattern of laser pulses results in an area of deep compressive stress
- Results of industry and government testing shows that laser peening stops or significantly inhibits crack initiation and propagation in blades



## Nd:Glass Laser System – Two Beams at up to 50 Joules Per Beam



*Small Parts Peening Cell  
(Turbine Airfoils)*

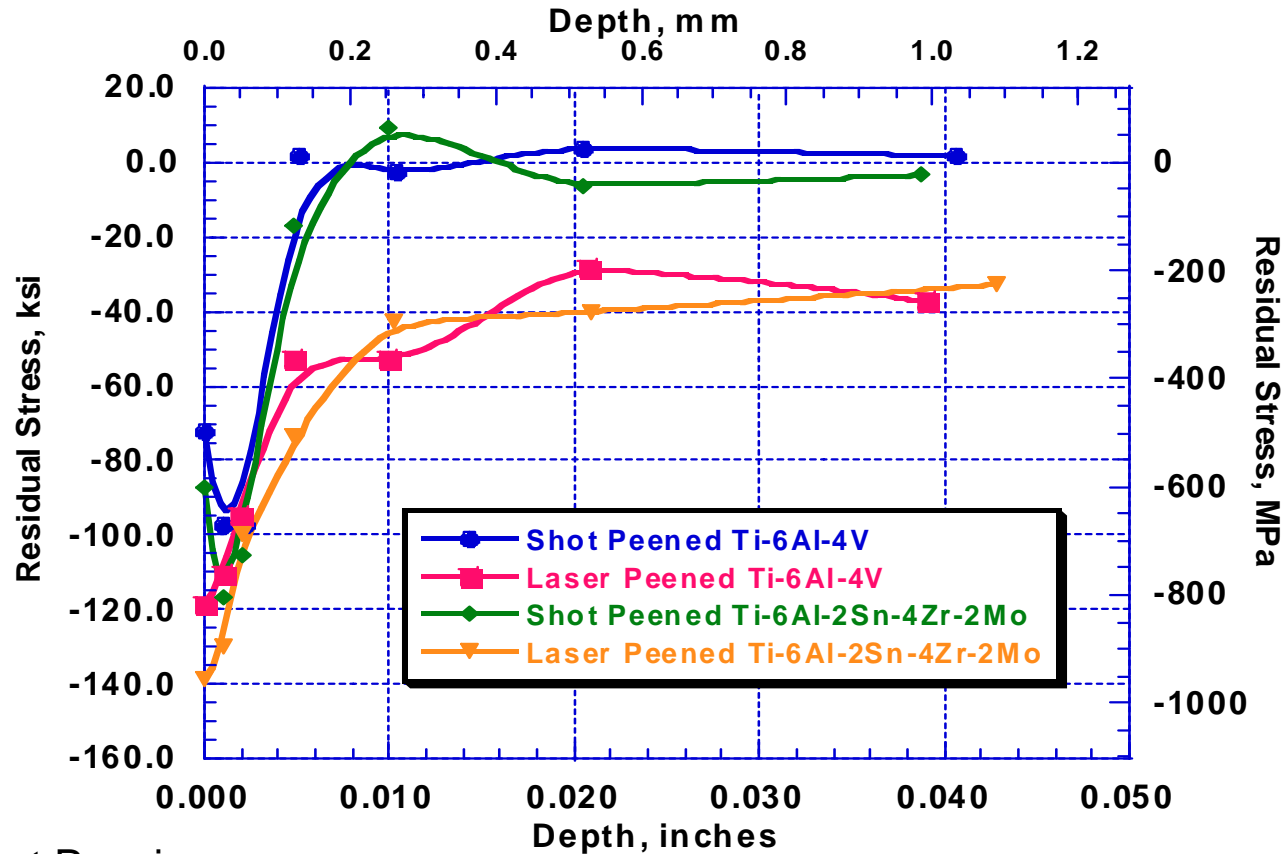


*Large Parts Peening Cell  
(Integrally Bladed Rotors)*

**MC Laser System (2-beam) Operates at 1.25 Hz (every 0.8 seconds)**

# Residual Stresses

## Laser Peening versus Shot Peening



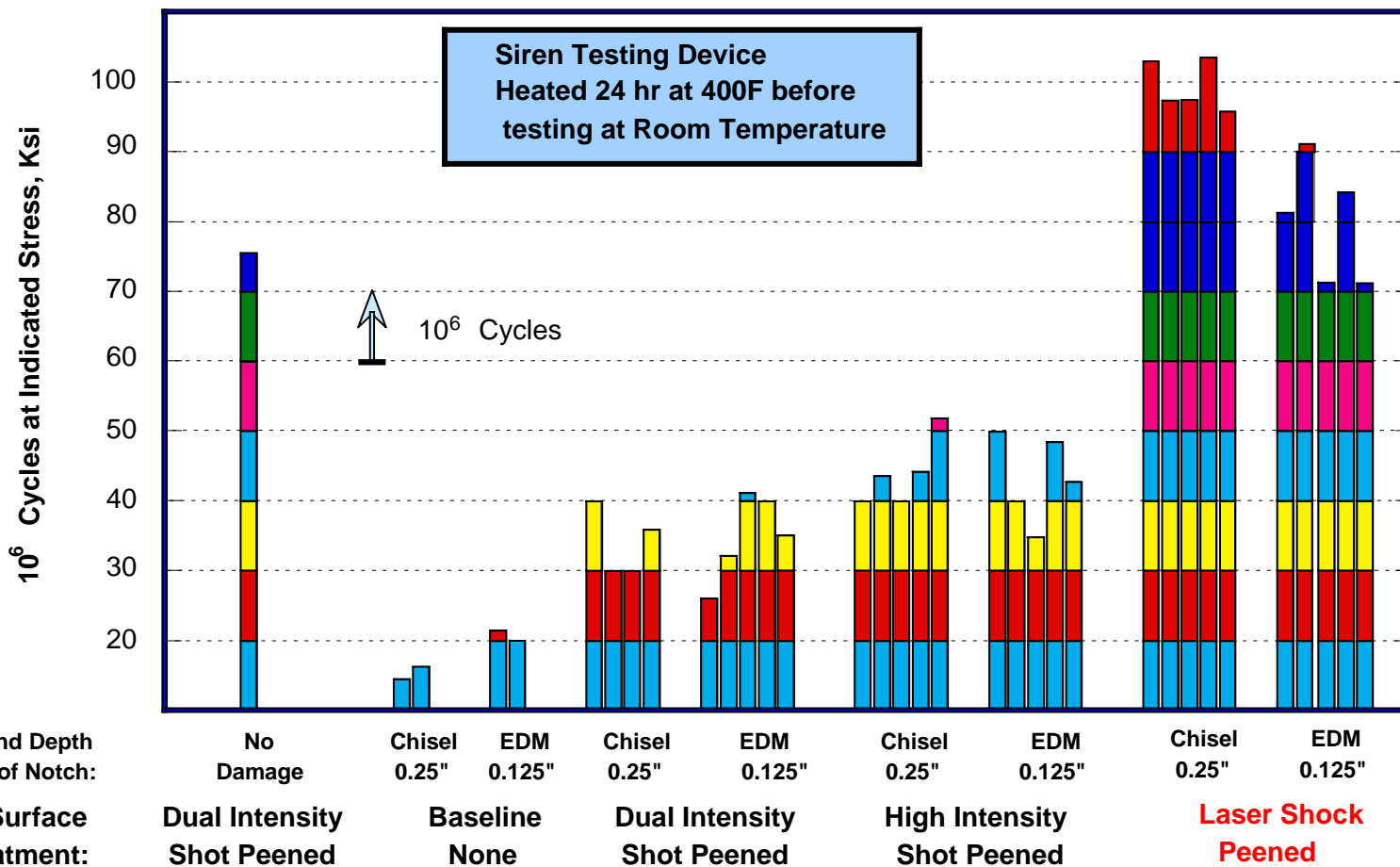
Shot Peening

—Residual Stress depth ~0.1 mm (0.004 inches)

Laser Peening

—Residual Stress depth 1 to 1.5 mm (0.040 to 0.060 inches)

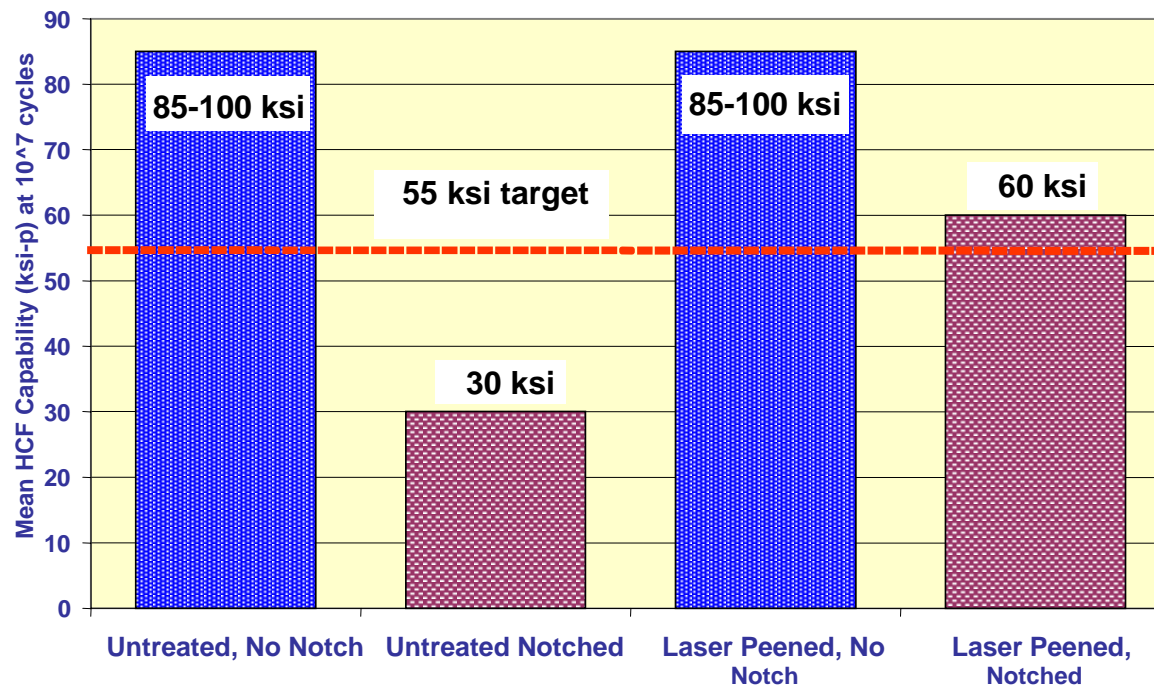
# Testing Results of Fan Blades after Simulated FOD



After See, Thompson and Sampson, Air Force Research Laboratory, USAF

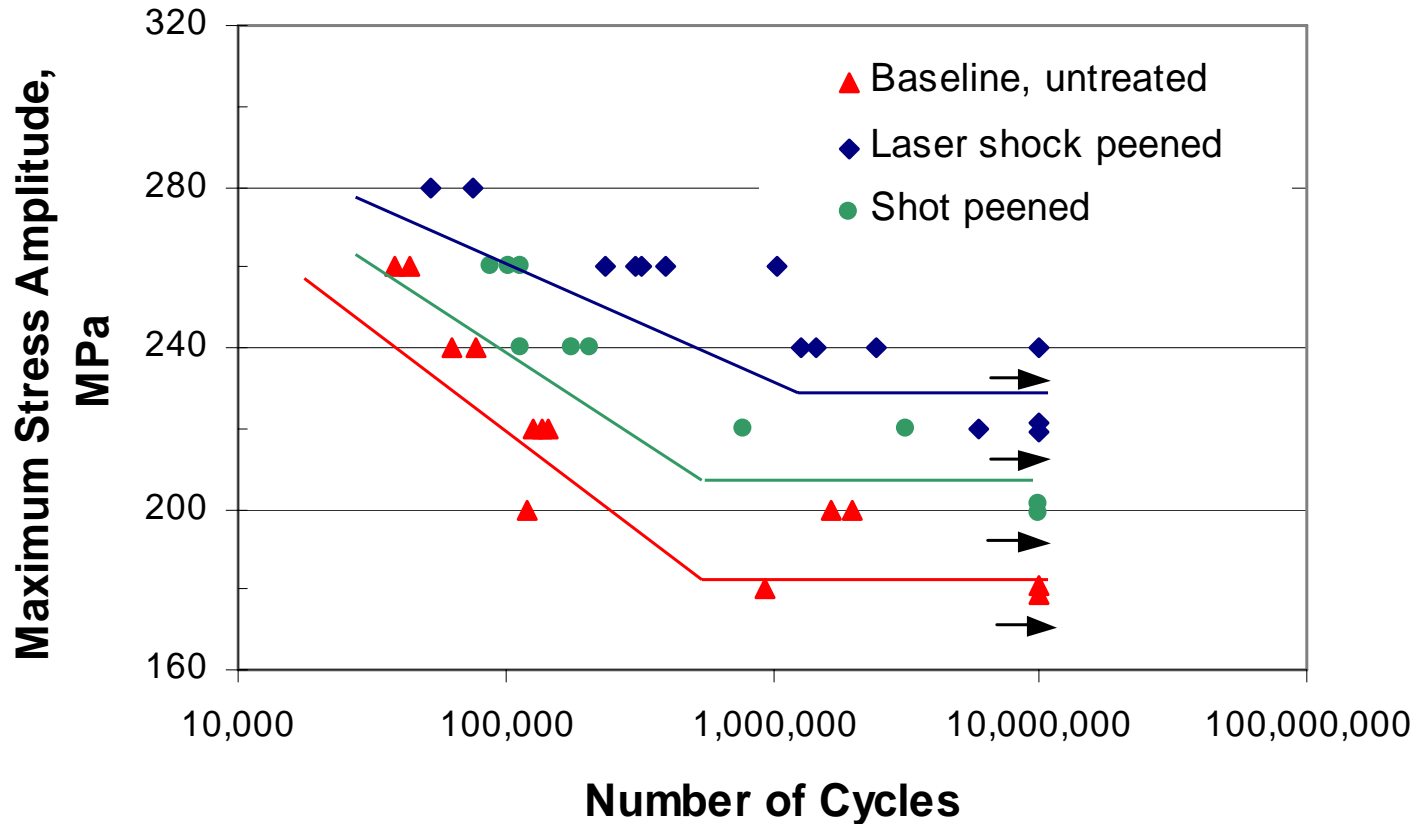
- Laser peening increases notched fatigue strength of IBR airfoils above the fatigue strength design criteria
- Initiative established the first production-ready IBR Peening Cell

Effect of Laser Peening on F119 IBR Fatigue Life



**Increased notched\* fatigue strength and FOD resistance on laser peened F119 IBRs**

\* EDM Notch 0.050-inches deep

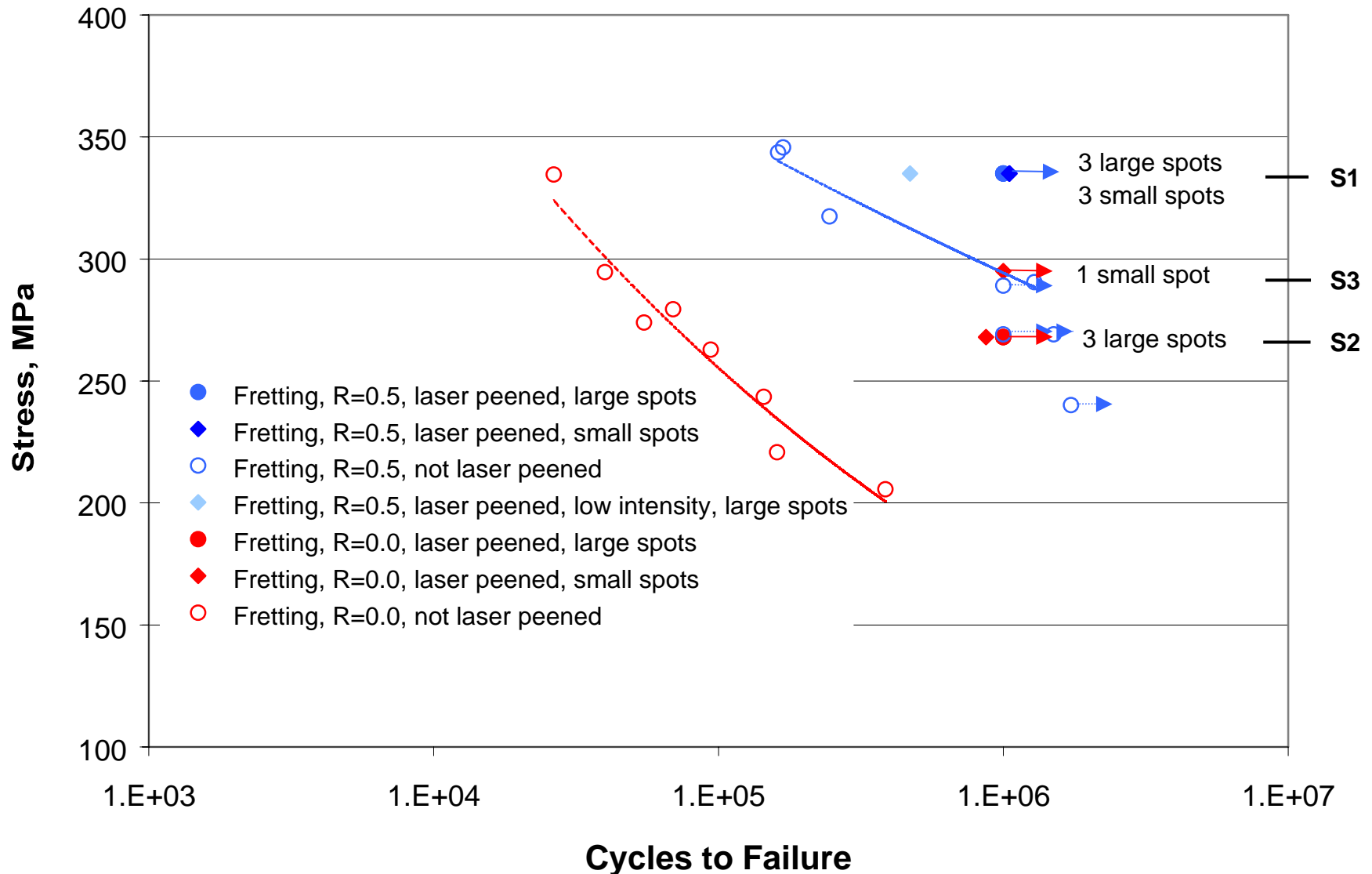


## 7050-T351 Aluminum

4 GW/cm<sup>2</sup>

3-point bending, R=0.1, Notched:  $K_t=1.68$

After P. Peyre, et.al.



# Evolution of Laser Peening Production Applications



*B1-B Lancer, F101-GE-102 Engine*



*F/A-22 Raptor, F119-PW-100 Engine*



*F-16 Falcon, F110-GE-100,129 Engines*



# Laser Peening of Army Aviation Applications



*Apache*



*Chinook*



*Blackhawk*

**Tougher Drive Systems for Higher HP Helicopter Versions  
Needed for High Altitude Missions such as Afghanistan**

# Army Helicopter Gears



- **Chinook Transmissions**
  - Engine - Gear tooth root
  - Forward - Planetary gears
  - Aft - Spiral bevel gear
- **Apache**
  - Main rotor transmission shaft – Upper and lower splines



**ARL/Penn State & Gear Research Institute – Gear testing program underway to evaluate laser peening effects on gear bending fatigue.**



**Boeing Helicopters - Investigating effects of laser peening for CH-47 horizontal hinge pins**



*Bell 430 helicopter*



*2nd-3rd Stage IBR*

**Rolls-Royce – Investigating laser peening to prevent fatigue failures originating at corrosion pits.**

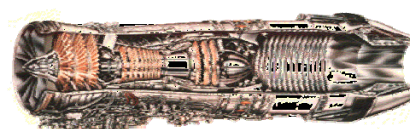
## LaserPeen® Processing of F110-100 Turbine Engine Blade Using the RapidCoater™ System



**LSPT's automated RapidCoater™ system reduces the processing time from ~33 minutes (with tape) to less than 6 minutes!**



**F-16 Falcon**



**F110 Engine**

# Laser Peening of Hidden Surfaces

## New Growth Area

### Issue with Current Systems

- Dovetail slots have limited line-of-sight access (hidden surfaces) due to high aspect ratio (slot length to width)

### Approach

- Reduce laser beam size
- Use the similar power densities to generate deep compressive stresses
- Deliver laser beam through articulated arm to processing pen

### Benefits

- Reduced laser system costs
- Smaller laser system footprint
- Provides improved fretting fatigue resistance

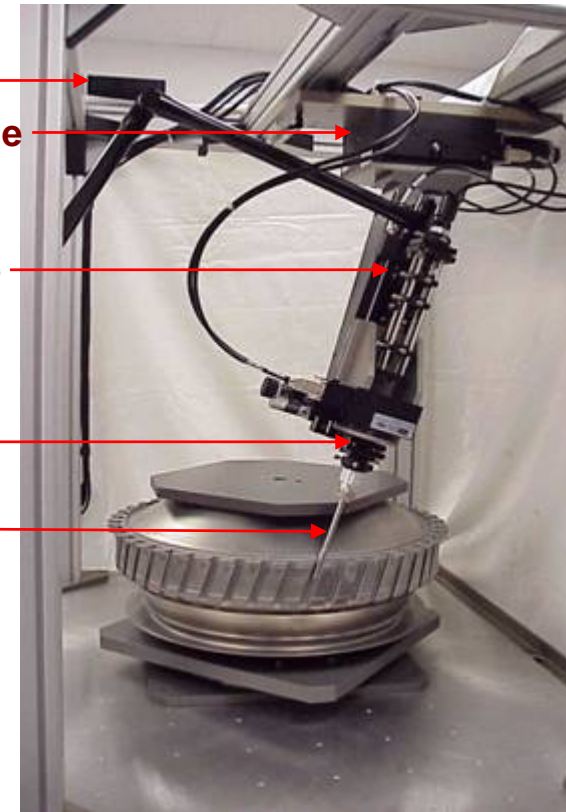
Articulated Arm

XY Translation Stage

Z Translation Stage

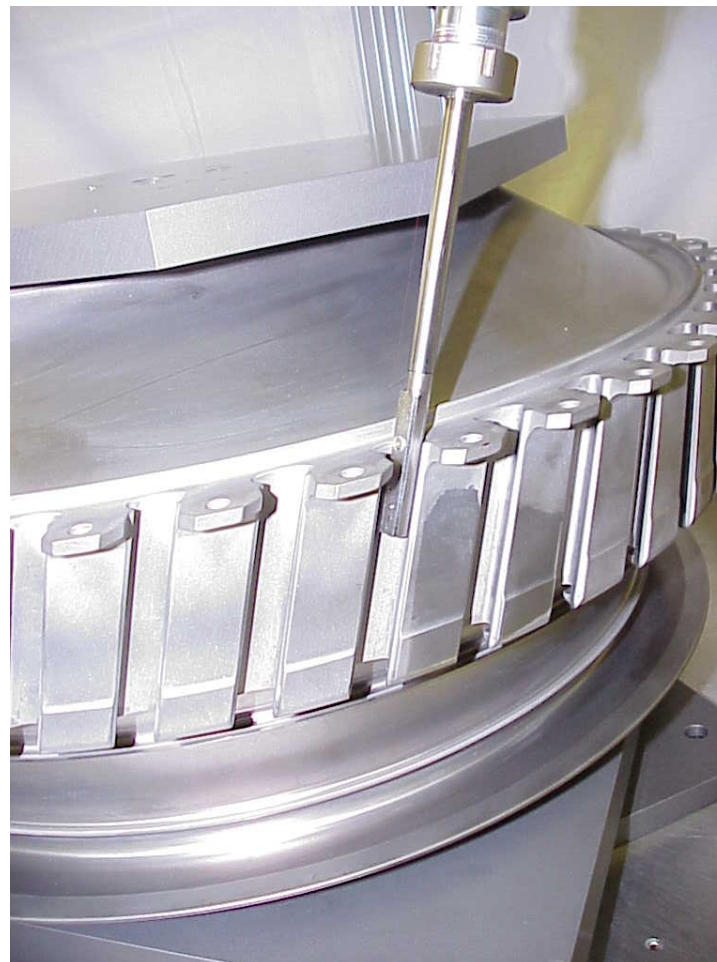
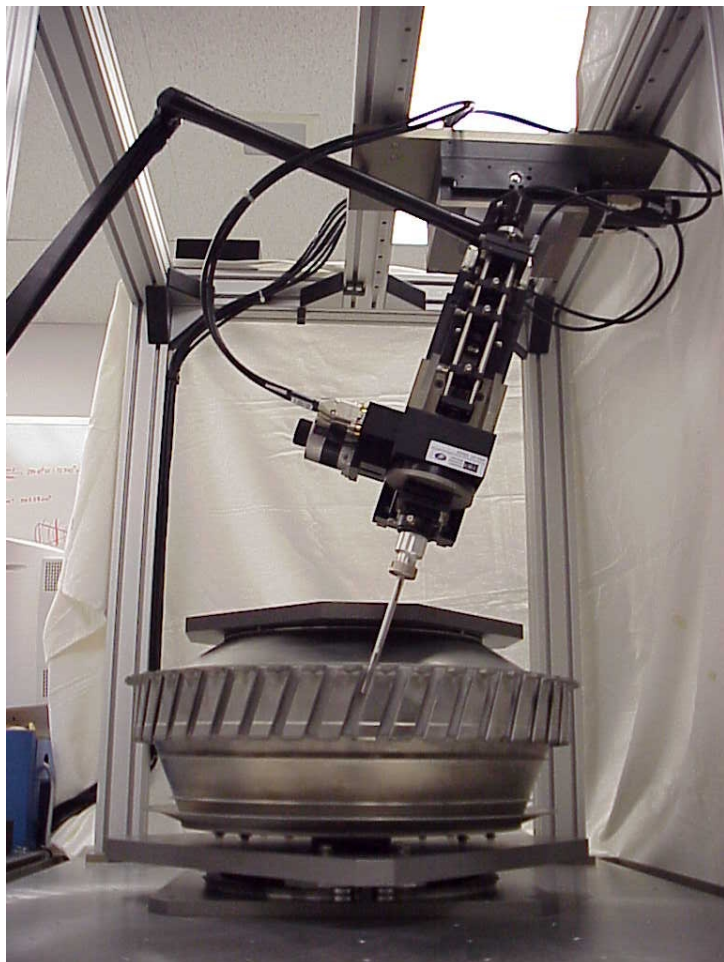
Rotary Stage

Processing Pen



Demonstrated laser peening on F110-GE-400 2<sup>nd</sup> stage fan disk with prototype system

# Laser Peening of Dovetail Slots

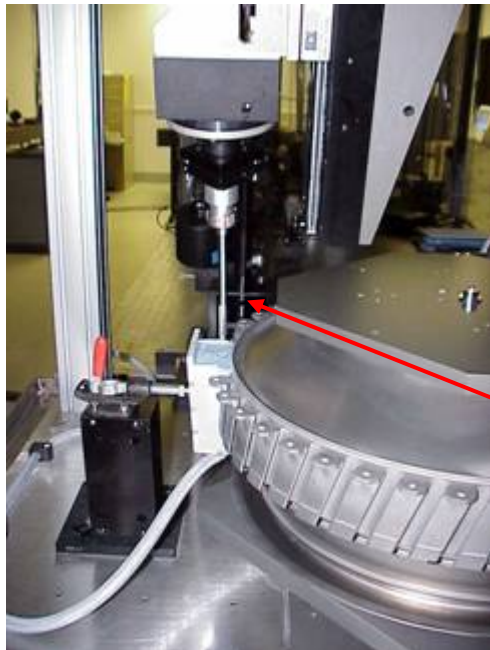


# Laser Peening of Hidden Surfaces AF SBIR II Enhancement Program

**Contract No. FA8650-05-C-5303**

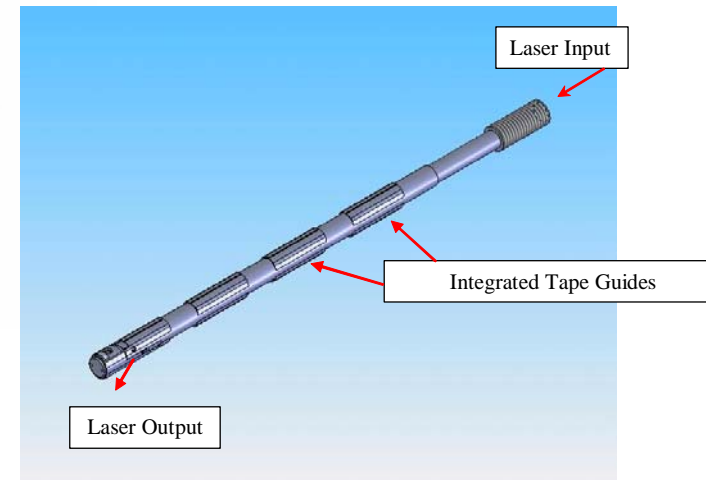
**Program Goal:** Develop a pre-production laser peening system based on a commercially-available, high-repetition-rate laser system using LSPT's small spot processing approach and articulated arm beam delivery.

**Additional Benefit:** Small-scale system components can be integrated into a portable unit for deployment at AF repair depots in a follow-on engineering effort once high-repetition-rate laser peening is validated.



Continuum 9050 small-spot,  
high-repetition-rate laser  
system

Processing pen



Processing pen schematic for  
laser peening recessed areas

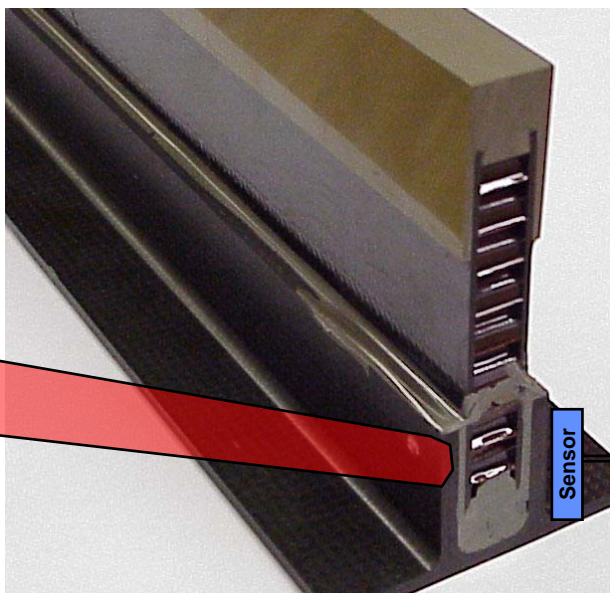
# Laser Bond Inspection



**Boeing 787**



**Boeing UCAV X-45**



***Inspecting to Ensure Bond Strength***

# Burst Laser System for Standoff Mine Neutralization



10-kW continuous laser works, but is slow and not mobile

10-kW pulsed burst laser is much more efficient and will be mobile

